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ABSTRACT

The validity of a spatial visualization test for selecting candidate engineering students was assessed. The test was administered to 300 out of the 318 students enrolled during the winter quarter of 1989 in the Engineering Graphics 110 course at a major state university. Developmental steps undertaken to enhance the theoretical basis and validity of a preliminary version of the test are reported. The 48-item multiple-choice test was developed based upon an analysis of mental processes used by engineering graphics experts. Two major skills, visual synthesis and decomposition, were identified. Within these major skills, four other skills were identified: pattern recognition, two-dimensional versus three-dimensional visualization, ability to move images mentally, and ability to perceive an object from another direction by an orientation or rotation method. Scoring of tests and report generation were handled on a microcomputer. Results of the test administration were correlated with Scholastic Aptitude Test (SAT) and American College Test (ACT) scores as well as with engineering graphics course examination scores. Results indicate that the new test is a better student selection device than are the currently used SAT and ACT scores. Two sample test items and one data table are included. (TJH)

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A SPATIAL VISUALIZATION TEST FOR SELECTING ENGINEERING STUDENTS

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The Ohio State University

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A Spatial Visualization Test for Selecting Engineering Students

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The validity of a selection test is dependent upon the steps taken to represent the theoretical basis of competence in the test development process. A new Spatial Visualization Test was developed based upon an analysis of mental processes used by engineering graphics experts. Two major skills, visual synthesis and decomposition, were identified. Within these major skills, four other skills were identified: pattern recognition, 2 versus 3-dimensional visualization, ability to move images mentally, and ability to perceive an object from another direction by an orientation or rotation method.

This 48-item multiple-choice test was administered to 300 engineering students. The results were correlated with SAT and ACT scores, as well as, with engineering graphics course exam scores. The results indicated that the new test is a better selection device than the correctly used SAT and ACT scores. Further validation is recommended.

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A Spatial Visualization Test for Selecting Engineering Students

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Lack of spatial visualization skills accounts for a substantial failure/withdrawal rate in engineering (Bertoline, 1988). There is, however, no dearth of spatial visualization tests. The International Directory of Spatial Tests (Eliot and Smith, 1983) describes hundreds of such tests. The research challenge is to identify specific visualization skills needed for mastering engineering graphics. Creating a test that would assess these specific visualization skills was the task undertaken by this study.

Spatial visualization has been tested in terms of visual memory, form recognition, block counting, paper folding, object manipulation, and surface development and perspectives (Eliot and Smith, 1983). Rather than select a readymade test purely on the basis of its statistical qualities, it was decided to first identify the domain of spatial skills needed for success in engineering graphics, and then select a suitable combination of test items for potential future use as a selection device.

The purpose of this paper is to present the developmental steps undertaken to enhance the theoretical basis and validity of a preliminary spatial visualization test developed for engineering students.

Study Design and Rationale

The new standards for Educational and Psychological Testing (AERA - APA - NCME, 1985) emphasize the importance of an underlying theory to ensure test validity. Recognizing that spatial visualization encompasses a large number of specific and somewhat disparate skills, it was decided to interview students who had been judged successful in engineering graphics by faculty. The students were asked to describe aloud the mental activities that they engaged in while solving the following typical engineering graphics problems:

- Given an isometric view of an object, sketch three orthographic views of the object.
- Given three orthographic views of an object, sketch a 3-D representation of the object.
- Given two orthographic views of an object, sketch the third orthographic view.

Two major skills identified were synthesis (putting several parts together into one whole) and decomposition (separating a composite picture into components). Four other skills specific to spatial visualization were also identified. These included the usual pattern recognition (shape, size, spatial relationship), two and three-dimensional visualization, ability to move images mentally,and ability to perceive an object from another direction by an orientation or rotation method. There was no existing test in the International Directory that represented all these six skills.

It was decided to create a multiple-choice (group, paper-and-pencil) test that would measure these six types of skills and provide diagnostic feedback for remediation. A test construction technique developed by D'Costa (1984) for professional self-assessment was used. Each test-item was targeted to a specific objective related to the competency domain. The test resulted in six scale scores and a total score. Additionally, the four distractors in each item were targeted to specific skill deficiencies or errors. See Figure 1 for a simple item from the new test. A special scoring system was utilized to assign partial credits based on the seriousness of the error. The system provides individualized feedback on skill strengths/weaknesses and the type of spatial visualization errors committed.

For the purposes of this research paper, it was hypothesized that a test developed on such theoretical bases would be more predictive of success in engineering graphics than currently-used selection tests, specifically the SAT and ACT. Specifically, scores from the new test were correlated with Engineering Graphics course points (marks), along with the SAT scores and ACT scores.

Methodology and Analysis

The new Space Visualization Test was developed following the usual developmental testing and pre-testing procedures. The final test booklet had 48 items, one practice/sample item with directions for solving the spatial visualization problem, and a standard set of group test-administration instructions. A separate NCS General Purpose answersheet was used to facilitate optical scanning. Scoring and report-generation were handled on a microcomputer.

The study sample comprised all students enrolled in Engineering Graphics 110 during Winter Quarter of 1989 at a major state university. The test was taken by 300 of the 318 students enrolled in the course. Additional student data, including SAT and ACT scores, were obtained from departmental records, following necessary approval procedures.

Data was gathered on 19 criteria variables (course exam score, six ACT scores, five SAT scores, six test scales scores,

and one total test score). The statistical system "MINITAB" was utilized to compute intercorrelations. Given the exploratory nature of this study, no tests of significance were conducted.

Findings and Conclusions

The reliability estimates for the test as a whole was 0.90. None of the items indicated negative discrimination. Scale homogeneity analyses showed that the six scales were well-defined and highly consistent within themselves. The intercorrelations among the six scales showed that complex rotation skill is a key factor in the competency domain. Lack of this skill affects all other skills. When complex rotation skills are not involved, synthesis and decomposition skills become separately important.

The validity studies based on this test show that it is a much better predictor of Engineering Graphics than any of the ACT or SAT test scores. The complex rotation skills scales were better predictors than any of the other scales. As expected, SAT-Verbal was negatively correlated with Engineering Graphics.

It is recommended that further research studies be conducted to confirm the predictive power of this new test. It is likely that a revised version of the test, emphasizing items with complex rotation skills might be an even more effective predictor of Engineering Graphics skills.

References

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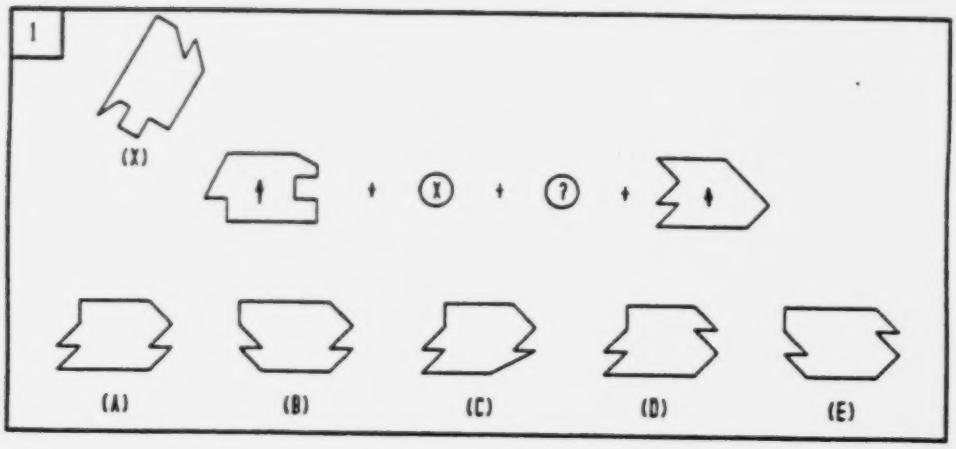
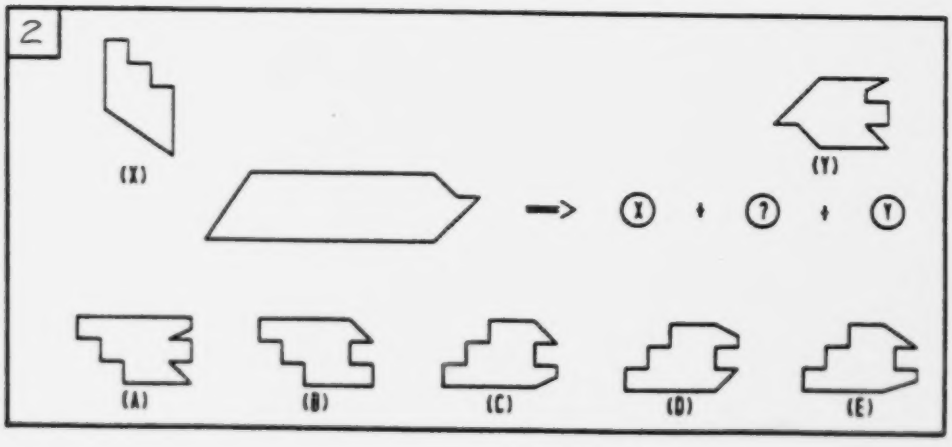
ENABLING SKILLS

1. Identify a pattern
2. Mentally perceive a 2-D and 3-D image
3. Mentally move image around
4. Mentally construct image from its parts
5. Mentally decompose image into its parts
6. Mentally perceive an image from another orientation

Sample Quiz





Answers: 1) a; 2) c

ERROR IDENTIFICATION

1. Size/ shape error
2. Mirror--mate error
3. Relative relationship error
4. Combination error

Correlations of Course Exam and Spatial Test to ACT and SAT and Spatial Test

	Course Exam	Spatial Test
Course Exam	xxxx	.395
ACT English	.175	.156
ACT Natural Science	.262	.201
ACT Math	.180	.089
ACT Comps	.229	.141
ACT Social Sciences	.170	.004
ACT Predictor GP	.359	.114
SAT Verbal	-.018	-.047
SAT Vocabulary	.056	.060
SAT Math	.127	.171
SAT TSWE	.038	.053
SAT Reading	.015	-.047
Spatial/ Synth--no rotation	.290	.434
Spatial/ Decomp--no rotation	.190	.508
Spatial/ Synth--elem rotation	.259	.674
Spatial/ Decomp--elem rotation	.314	.644
Spatial/ Synth--adv rotation	.357	.951
Spatial/ Decomp--adv rotation	.363	.950
Spatial Test	.395	